

Altitude, Frost and the Distribution of White Box (*Eucalyptus albens*) on the Central Tablelands and Adjacent Slopes of NSW

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The apparent rarity of white box (*Eucalyptus albens*) at high altitude has been explained by assuming an intolerance to low temperatures. These propositions were assessed by (a) a field survey of the occurrence of white box at high altitude on part of the NSW Central Tablelands and adjacent slopes and (b) a pot trial study of the response of seedlings of white box and yellow box (*E. melliodora*) to low temperatures during winter 1997. The field survey confirmed that, unlike yellow box, white box was absent from a large part of the Central Tablelands. However, it was recorded at altitudes up to 925 m a.s.l. near Orange but at lower altitudes further south. Aspect was not limiting at high altitude though low slopes appeared to be. Survival and growth of white and yellow box seedlings were low at the high altitude site but there was little difference between species regardless of whether frosted seedlings were subjected to early or delayed exposure to direct morning sunlight. Hence, alternative explanations for the local distribution pattern of white box on the Central Tablelands and adjacent slopes need to be examined.

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INTRODUCTION

White box (*Eucalyptus albens* Benth.) extends from south-east Queensland along the slopes of NSW to central Victoria. Disjunct populations occur in eastern Victoria, western Victoria and the Southern Flinders Ranges of SA. The most recent description of the habitat of *E. albens* was prepared by Prober and Thiele (1993) and draws heavily on previous accounts. They reported that it generally occurs on fertile soils derived from a wide variety of parent materials. Within its area of occurrence, mean annual rainfall ranges from 500 - 800 mm, mean maximum temperature in the hottest month 27 - 32 °C, mean minimum temperature in the coldest month -1 - 5 °C and frost frequency 5 - 70 per year.

Cabbage (1902) and Beadle (1981) suggested that its absence from higher parts of the tablelands was due to 'coldness' or intolerance of heavy frosts. It has been recorded at high altitude but its upper altitudinal limit is difficult to determine as altitude is rarely recorded on locality details accompanying

herbarium specimens. Actual and apparent altitude records in CSIRO's (since discontinued) Eucalust, Victorian Flora Information System and NSW National Herbarium databases (Table 1) indicated a record at ~1060 m above sea level (a.s.l.). Boland et al. (1984), however, reported an occurrence from an unspecified locality, possibly in northern NSW, at 1200 m a.s.l., some 600 m higher than in an earlier edition of this publication (Hall et al. 1970).

Though frosts are common at high altitudes, they are also common in 'frost hollows' produced by cold air drainage at lower altitudes. Hence, if *E. albens* is intolerant of heavy frosts it would not be expected to occur in depressions subject to frequent frosts. The relative occurrence of *E. melliodora* Cunn. ex Schauer (yellow box) and *E. albens* in the Central Western Slopes and Central Tablelands botanic subdivisions of NSW (explained and mapped in various editions of Anderson, e.g. 1968) suggests that this may be the case. For example, around Bathurst ~670 m a.s.l.), which is located in a basin subject to

Table 1. Some high altitude records (metres above sea level) for *E. albens* across its natural range from north to south. Sources: CSIRO’s ‘Eucalist’ (since discontinued), Victorian Flora Information System (VFIS), National Herbarium of NSW (NSW).

Specified altitude	Possible maximum altitude	Location	Source(1997)
900	-	Glenn Innes - Emmaville, NSW	Eucalist
-	850	Top of Mt. Wallaby, Woolomin	NSW
-	1100	Hanging Rock, Nundle, NSW	NSW
780	-	WSW of Quirindi, NSW	Eucalist
-	1060 ^A	Pinnacle Lookout [Coolah Tops]	NSW
731	-	Wattle Flat - Sofala	Eucalist
-	960 ^B	Mt. Remarkable, S.A.	Eucalist
-	1204 ^C	Mt. Mcquarie, Blayney, NSW	NSW
900	-	South of Suggan Buggan, Vic.	VFIS
850	-	Southeast of Suggan Buggan, Vic.	VFIS
-	704 ^D	The Paps, Mansfield, Vic.	NSW
-	1167 ^E	Mt. William, Grampians, Vic.	Eucalist

^A. Confirmed by M. Sharp (pers. comm., 2001) who also noted that *E. albens* occurs elsewhere in Coolah Tops National Park at elevations up to ~1090 m a.s.l.
^B. Occurs on the southern foothills but is unlikely to extend to summit ridge (W. Semple, personal observations).
^C. Most likely a record from the slopes of Mt. Macquarie, where *E. albens* occurs up to at least 870 m a.s.l. (this paper). A summit location cannot be confirmed due to its conversion to exotic pine forest.
^D. Not observed above 550 m a.s.l. on this hill (J. Lawrence, pers. comm., 2001).
^E. Probably a mis-identification as *E. albens* is not mentioned in Elliot et al. (1984).

cold air drainage, *E. melliodora* occurs in both the basin and at higher altitudes, whereas *E. albens* is restricted to the latter (e.g. towards Hill End). Around Orange (800 - 900 m a.s.l.), which is located on a plateau, *E. melliodora* is relatively common up to ~900 m a.s.l. but *E. albens* is rare. However, within the Central Western Slopes, *E. albens* commonly occurs on hills and slopes and *E. melliodora* on flats and lower slopes. These patterns could be explained, at least partially, by assuming that *E. melliodora* has a higher tolerance to frost than does *E. albens*. This explanation is at variance with other authorities and local observations. For example, Bower et al. (2002) reported that *E. melliodora* is more common on more fertile, though perhaps less well-drained, soils than *E. albens*. Though *E. albens* is not typically associated with poor soils, its local distribution pattern is often explained in terms of differences in soil properties (e.g. Prober 1996).

If frost does affect the local distributions of *E. melliodora* and *E. albens*, it would be expected to operate at a sensitive stage of the life cycle, viz. the seedling, especially those that emerged in autumn or

winter. According to Cremer (1990), frost can affect young seedlings in three main ways: (a) ‘wilting’ where leaves become flabby and darkened with a waterlogged appearance, which is followed within days by drying; (b) damage to roots which are more sensitive than shoots; and (c) ‘frost heave’ where the stem of the seedling is gripped by a frozen soil crust and forced upwards by underlying ice crystals resulting in roots being detached from the soil. A further possibility is that of ‘stress-induced photoinhibition’ where photosynthetic capacity is reduced in stressed seedlings and that under high light conditions, more light energy is absorbed than can be used or dissipated. The visual effects of this would presumably be leaf death similar to ‘wilting’. Based on work by Ball et al. (1991), Egerton (1996) proposed chronic cold-induced photoinhibition as a major reason for the absence of eucalypt seedlings growing to immediate north of *E. pauciflora* Sieber ex Sprengel trees near Canberra. However, earlier work with ~30 cm tall, frost-hardened, subalpine eucalypt seedlings in a radiation frost room by Harwood (1980) indicated no difference in leaf damage between

seedlings that were exposed, on one occasion only, to bright sunlight v. darkness following frosting.

As part of research into the factors affecting the recruitment of *E. albens*, its local distribution pattern around Mt. Canobolas on the Central Tablelands of NSW was investigated in the mid 1990s. Preliminary results (Semple 1997) indicated that *E. albens* mainly occurred on slopes with non-easterly aspects at altitudes above 780 m a.s.l. On the basis of these results and Egerton's (1996) hypothesis, the survey was extended to a wider area and the effects of low temperatures on young eucalypt seedlings were investigated in a pot trial during winter 1997. The hypotheses tested in the pot trial were that (1) seedlings of *E. albens* are less frost tolerant (as assessed by survival and indices of growth) than those of *E. melliodora* and (2) frosted seedlings of *E. albens* (and possibly those of *E. melliodora*) are adversely affected by exposure to direct sunlight.

METHODS

Upper altitudinal limits of *E. albens* on the tablelands and adjacent slopes

Over a number of years, roads radiating from two local high points, Mt. Canobolas (1397 m a.s.l.) and Mt. Macquarie (1204 m a.s.l.) were examined for the highest occurrences of *E. albens*. Each location was plotted on a map and altitude and aspect recorded. Trees, which could be confidently identified in adjacent paddocks, were also included in the survey. All 11 sites in Semple's (1997) earlier survey were revisited.

It was appreciated that the reduced likelihood of roads traversing the highest points in the landscape, the absence of public roads in some areas, and selective tree removal on roadsides were potential sources of error in this technique.

Effect of frost \pm early morning sunlight on seedlings of *E. melliodora* and *E. albens*

Seedlings were raised in 30 cm diameter x 27 cm deep black plastic pots containing sandy loam topsoil from an *E. albens* site at Cowra overlain by ~2 cm of seed-raising mixture. A slow-release fertiliser was mixed with the soil in all pots in an attempt to overcome any nutritional problems that may have adversely affected *E. melliodora*, which usually occurs on fertile soils. Half of the 16 pots used in the experiment were randomly allocated to seed (collected from around Molong on the upper Central Western Slopes) of *E. albens* and the other half to *E. melliodora* in early March 1997. Seedlings and

weeds were progressively removed until 30 similar-sized seedlings of either species were present in each pot. Due to settling of the soil, the rim of each pot was later cut down to ~2½ cm above the soil surface. At the commencement of the experiment on 1 May 1997, seedlings were at the four to six leaf stage with those of *E. albens* generally being more advanced due to earlier emergence.

Two pots of each species were randomly allocated to four treatments, consisting of the factorial combination of light (Delayed or Early Light) and location (Orange, 870 m a.s.l. or Cowra, 380 m a.s.l.). The Delayed Light treatment was realised by placing pots ~1 m to the west of an existing or constructed north-south opaque steel fence, thereby delaying exposure to direct morning sunlight until 1035 hours (early July) at both locations. The Early Light treatment was achieved by placing the pots in an open area exposed to direct sunlight at 0740 hours (early July) at Cowra and 0805 hours at Orange where 'sunrise' was delayed by topography and vegetation. Pots were watered as required, avoiding prolonged waterlogging. At 1 to 2 weekly intervals, the positions of the four pots in each location by light treatment were rotated. Each pot was also rotated through 180° in an attempt to evenly distribute shading from the rim of the pot. At the same time, seedlings were counted, dead plants removed and apparent cause of death noted.

On 15 September 1997, each seedling was assessed for height of main stem (from the cotyledons to the upper-most live leaf) and the number of live pairs (or part pairs) of seedling leaves on the main stem. Pots with high numbers of healthy plants (viz. all those at Cowra) were systematically thinned to about 15 plants per pot. On 13 October when the likelihood of further frosts was low, all pots were relocated to a concrete apron with an automated watering facility at Cowra to evaluate subsequent growth under uniform conditions. Seedling numbers were recounted in early November and, together with measurements of heights, in early January 1998.

Data (survival, mean numbers of leaves and mean heights) were analysed as a 2³ factorial design of Location (2) x Species (2) x Light treatment (2), replicated twice, using analysis of variance methods. Visual examination of residual diagnostic graphs indicated a non-normal distribution in the September seedling height data and a transformation to natural logarithms was carried out. Treatment means were examined for significant differences ($P = 0.05$) using the least significant difference (lsd) multiple comparison procedure (Steel and Torrie 1960).

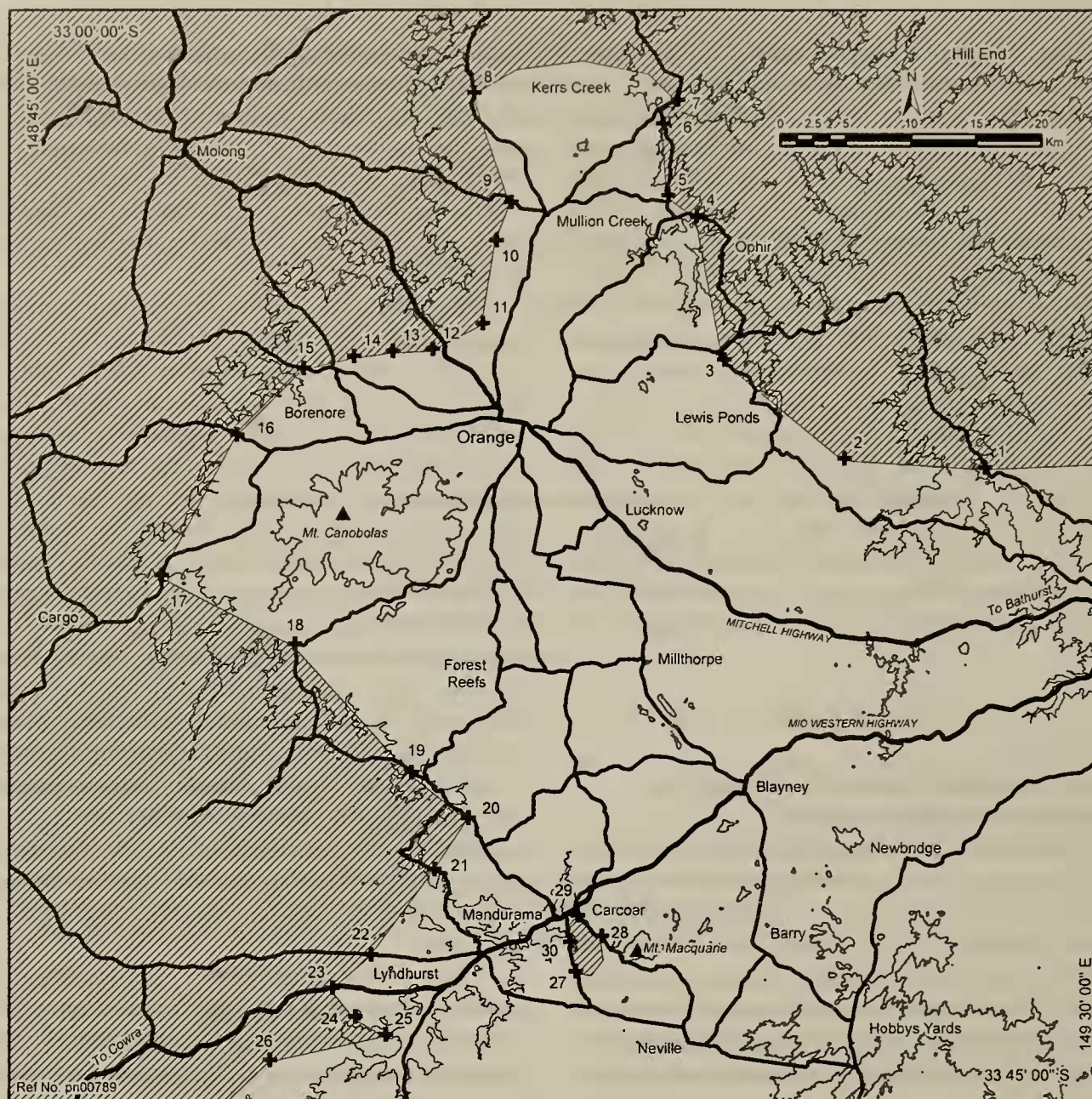


Figure 1. Part of the Central Tablelands and adjacent slopes of NSW showing areas where *Eucalyptus albens* is likely (hatched area, including the small area south of Carcoar) or unlikely (unhatched area) to occur. Numbered +s indicate locations of *E. albens* at the highest elevations on roads (thick lines). Thin lines indicate the 1000 m (near Mts. Canobolas and Macquarie and Hobbys Yards in the south-east) and 700 m contours.

RESULTS

Upper altitudinal limits of *E. albens* on the tablelands and adjacent slopes

Eucalyptus albens was absent from most roadsides above 900 m in the vicinity of Orange but to the south-west, its highest occurrence was rarely above 750 m a.s.l. It was absent from many roadsides, particularly those to the south-east of Orange. The occurrence or non-occurrence of *E. albens*, as determined in the roadside survey, is shown in Fig. 1. All occurrences were of mature trees though regeneration was evident at some sites.

Elevation

Thirty main sites (Fig. 1) and nine nearby subsidiary sites were identified as being the highest elevation occurrences on the roads travelled. The highest elevations were recorded near Orange: to the east on the fall of the Central Tablelands to the Macquarie River valley (925 m a.s.l., site 2) and to the north (890 m a.s.l., site 9a) on the western fall of the tablelands. A disjunct population at high elevation (up to 870 m a.s.l., site 28) was also recorded near Carcoar on the western and north-western slopes of Mt. Macquarie. The site with the lowest elevation (660 m a.s.l., site 23) occurred west of Lyndhurst on the Mid

Table 2. Mean monthly terrestrial minima and frost frequencies at the Orange Agricultural Institute^A (1975-96) and the Department of Infrastructure, Planning and Natural Resources Research Centre at Cowra^B (1943-97), together with monthly data for 1997.

	Terrestrial minima (°C)				Frost ^C frequency (days/month)			
	Cowra (mean)	Cowra 1997	Orange (mean)	Orange 1997	Cowra (mean)	Cowra 1997	Orange (mean)	Orange 1997
May	3.3	4.6	2.2	2.1	6.3	3	7.1	8
June	1.3	-1.2	-0.2	-2.5	10.9	19	13.6	24
July	0.1	-1.8	-1.2	-4.1	13.9	20	18.1	28
Aug	0.8	-0.9	-0.8	-2.7	11.2	19	16.3	25
Sept	2.6	3.4	0.8	1.4	6.8	1	11.3	9
Oct	5.5	4.3	3.0	2.1	1.9	4	5.2	9

^A. 890 m a.s.l and 3.4 km from the Orange experimental site.

^B. 381 m a.s.l. and c.100 m from the Cowra experimental site.

^C. A frost was considered to have occurred when a minimum of ≤ -0.9 °C was recorded at 2.5 cm above grass.

Western Highway. Many other sites in the south-west were of relatively low elevation, e.g. sites 17, 19, 21, 22, 24 and 26 were at elevations below 750 m a.s.l. The situation was similar but less marked in the north-east (sites 3, 4, 6, 7 and 8).

Aspect

Approximately 25 % of the 39 occurrences occurred on crests and hence could not be allocated a single aspect though averaging was attempted. Virtually all occurrences, especially at higher altitudes, were on sloping land. No sites occurred in drainage lines but at one relatively low elevation site (720 m a.s.l., site 3a), *E. albens* extended down-slope to a drainage line. When each site was allocated an aspect (N, E, S or W quadrants), the numbers of sites in each quadrant declined from $W \approx N > E > S$. Of the 12 highest elevation sites, i.e. ≥ 800 m ASL, numbers in each quadrant were $W = E \approx N > S$.

Effect of frost \pm early morning sunlight on seedlings of *E. melliodora* and *E. albens*

Monthly terrestrial minima were lower and frost frequencies were higher than average at both sites from June to August 1997 (Table 2). During the main period of the experiment, 1 May to 12 October, 97 frosts were recorded at Orange and 63 at Cowra. Five or more days of consecutive frosts occurred on six occasions at Orange and seven at Cowra. The lowest terrestrial minima recorded were -8 °C at Cowra and -9 °C at Orange, both on 21 July. Frosts persisted for longer at Orange than at Cowra – particularly in the

Delayed Light treatment. The soil in the pots was often frozen at or just below the surface during midwinter in Orange.

Effect of frosts on seedlings

At Orange a progressive decline in numbers of seedlings of both species commenced in June (Fig. 2). Seedlings in the Early Light treatment were adversely affected initially but by mid August, mean numbers of survivors were similar in all treatments. Most deaths at Orange were frost-related, i.e. wilting and/or frost heave with the latter particularly affecting small (≤ 6 leaves) seedlings, which were more common in *E. melliodora* than in *E. albens* populations. None of the deaths at Cowra (20 by mid October) showed definite frost effects (Table 3).

In July, it was noted that some seedlings of both species had produced shoots in leaf axils as well from the cotyledon area, i.e. the site where the lignotuber would subsequently develop. When assessed in mid September, axillary shoots were present in 95 % of all seedlings and ‘lignotuberous shoots’ in 78 %. The early development of lignotuberous shoots apparently had no adverse effect on the development of lignotubers, which were present in 89 % of surviving seedlings in early January 1998.

Differences between treatments

Mean seedling survival (in October), main stem height and numbers of leaves (in September) were significantly higher at Cowra than at Orange (Table 4). Apart from mean numbers of leaves on *E. melliodora* seedlings being greater than on *E. albens*,

Table 3. Probable cause of death of seedlings (120 of each species initially) in both Early and Delayed Light treatments at (a) Orange and (b) Cowra between 1 May and 11 October 1997.

	Unknown	Frost heave	'Wilt'	Frost heave and 'wilt'	All causes
(a) Orange					
<i>Eucalyptus albens</i>	2	12	67	6	87
<i>E. melliodora</i>	5	32	31	2	70
(b) Cowra					
<i>Eucalyptus albens</i>	6	0	0	0	6
<i>E. melliodora</i>	14	0	0	0	14

there were no significant differences between the species across the two sites. Significant interactions suggested that mean height and number of leaves were significantly higher for all seedlings in the Delayed than in the Early Light treatment at Cowra but not at Orange; and that across both sites, *E. albens* seedlings were significantly taller in September in the Delayed than the Early Light treatment (Table 4).

Most of the seedlings present in mid October 1997 survived until early January 1998 at which time the mean height of seedlings raised at Cowra was significantly higher than those raised at Orange but the difference was less marked than previously. There were no other differences between species and treatments and their interactions (Table 4).

DISCUSSION

Natural occurrence of *E. albens* at high altitudes

The roadside survey data indicated that *E. albens* did not have a consistent upper altitudinal limit around Mts. Canobolas and Macquarie on the Central Tablelands of NSW. In the south-west of the study area it did not occur above 750 m whereas nearer to Orange it extended to elevations above 800 m. At the latitude of about Millthorpe (~33° 30' S), *E. albens* does not occur further east than is shown in Fig. 1 (apart from a recently-discovered, small disjunct population at 750 m a.s.l. on the northern footslopes of Mt. Panorama at Bathurst) despite the availability of other low elevation sites in the Bathurst Basin. It extends further east to the north of Orange (as shown) and to the south of the study area in the vicinity of Abercrombie, south of Blayney. Clearly, the Central Tablelands represent a barrier to the distribution of *E. albens* but on its own, altitude (and presumably frost severity) does not appear to be a limiting factor except at very high altitudes.

Other potential limiting factors include higher

rainfall and waterlogging, which may favour other eucalypt species on the tablelands, and soil differences. High altitude occurrences of *E. albens* were sometimes associated with certain soil landscapes (composites of soils, topography and lithology) as mapped by Kovac et al. (1990). The disjunct population near Carcoar was associated with 'Razorback' soil landscape (steep to rolling topography with shallow well-drained soils derived from the Sofala Volcanics) and occurrences north-east of Orange were loosely associated with 'Panorama' soil landscape (steep to level-crest topography with moderately fertile soils derived from Tertiary basalt) and similar areas too small to be shown on Kovac et al.'s map. A close association with basic igneous material was reported from the Macquarie region north of Dubbo by Biddiscombe (1963, p. 20), who suggested that 'soil nutrient status may be more decisive to *E. albens* than is moisture status'. However, further south in the South-eastern Riverina (Moore 1953) and Monaro (Costin 1954) regions, *E. albens* was reported to occur on a wide variety of soils and parent materials but generally on steep to undulating topography.

The earlier supposition that *E. albens* did not occur on easterly aspects (i.e. those likely to be exposed to early morning sunlight) at high altitude was not supported by the expanded roadside survey. This was clearly indicated by its presence on easterly aspects at the two highest altitude sites. The preponderance of northerly and westerly aspects on the western part of the Central Tablelands was probably responsible for the earlier supposition. As all of the higher altitude occurrences were on slopes, it is likely that low slope rather than aspect may be a factor that limits its occurrence at high altitude.

Differences between seedlings of *E. melliodora* and *E. albens* in the pot trial

Seedlings at Cowra performed significantly 'better' than those at Orange in all attributes measured

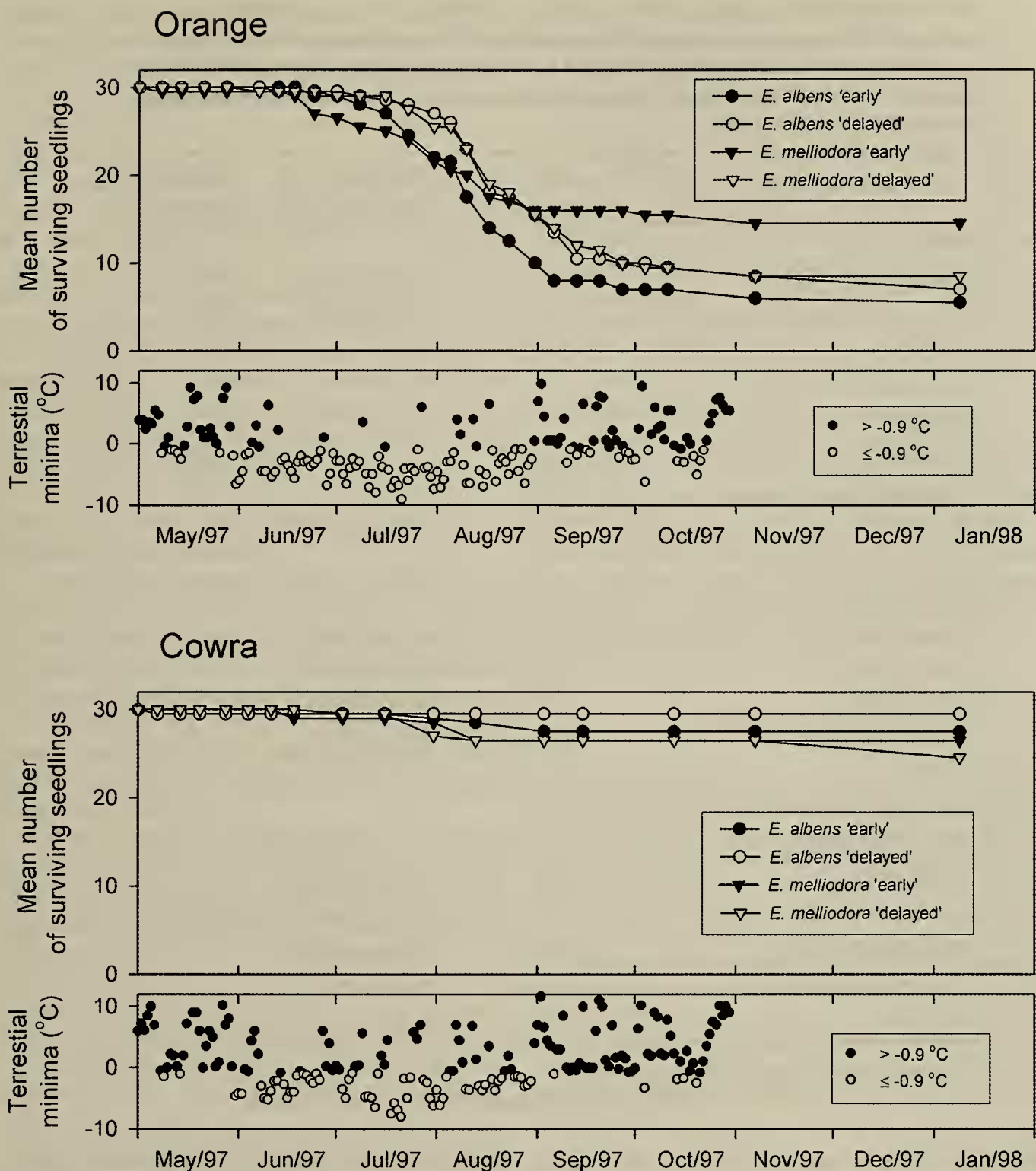


Figure 2. Survival of *E. melliodora* and *E. albens* seedlings under two morning light treatments, 'delayed' and 'early', during winter 1997 at Orange (870 m a.s.l.) and Cowra (380 m a.s.l.). Seedlings at Cowra were thinned on 15 September and numbers presented have been adjusted for this. All seedlings were relocated to an early light area at Cowra on 13 October 1997. Also shown are daily terrestrial minimum temperatures at each site. Open circles indicate frosts.

(Table 4). Conditions at Orange were particularly harsh during the 1997 winter and this was exaggerated by seedlings being in uninsulated above-ground pots where freezing of the topsoil occurred in midwinter. This was probably uncommon under normal conditions

at Orange and seedlings may have experienced conditions more typical of an altitude that was well above the site – a suggestion that would also apply to the Cowra seedlings. Seedling deaths at Orange were mainly attributed to frost heave and 'wilt'. Other

DISTRIBUTION OF WHITE BOX

Table 4. Differences in mean survival (at October 1997), numbers of leaf-pairs (September 1997) and mean stem height (September 1997 and January 1998) between seedlings of two eucalypt species exposed to two light treatments at two sites. Within columns in each section, values followed by the same lower case letter are not significantly different ($P = 0.05$).

	Survival %	Leaf-pairs per seedling	$\log_e(\text{Height}+1)$ Sept 1997	Height (mm) Jan 1998
SITE				
Orange (ca 870 m a.s.l.)	34.6 a	3.15 a	2.89 a (17.0) ^A	407 a
Cowra (ca 380 m a.s.l.)	91.7 b	7.41 b	4.39 b (80.0)	476 b
lsd (5%)	19.9	0.73	0.19	61
SPECIES				
<i>E. albens</i>	- ^B	4.53 a	-	-
<i>E. melliodora</i>	-	6.03 b	-	-
lsd (5%)		0.73		
SITE x LIGHT				
Orange Early	-	3.55 a	2.97 a (18.5)	-
Orange Delayed	-	2.75 a	2.81 a (16.7)	-
Cowra Early	-	6.75 b	4.18 b (64.1)	-
Cowra Delayed	-	8.07 c	4.61 c (99.5)	-
lsd (5%)		1.03	0.27	
SPECIES x LIGHT				
<i>E. albens</i> Early	-	4.08 a	3.50 a (32.0)	-
<i>E. albens</i> Delayed	-	4.97 a	3.82 b (44.8)	-
<i>E. melliodora</i> Early	-	6.22 b	3.65 ab (37.5)	-
<i>E. melliodora</i> Delayed	-	5.85 b	3.60 ab (35.6)	-
lsd (5%)		1.03	0.27	

^A. Back transformed means (mm) in parentheses.
^B. Only statistically significant main order and interaction effects have been tabulated.

presumed effects of frost at both Cowra and Orange were the production of shoots from leaf axils and the cotyledon or ‘proto-lignotuber’ area.
Though seedling densities in the pots were initially higher than would be expected in cases of natural regeneration, it was unlikely that the results were confounded by the effects of competition, which if operative, would have been more likely to affect growth than survival. At Orange, pots were not crowded due to the many deaths. Also, young woodland eucalypts, including *E. melliodora*, grow little if at all during winters at Orange (Semple and Koen 2001). At Cowra, where seedlings did grow and

deaths were few, densities in all pots were similar, including after thinning in September 1997. Competition effects would have been constant across treatments and hence, would not have confounded the relativity of the results.
There was no significant difference between the survival rates of the two species but it was possible that the susceptibility of the smaller *E. melliodora* seedlings to the unusual occurrence of frost heave at Orange (Table 3) may have masked differences at that site and possibly across sites in the analysis. The only significant difference detected between the two species was higher numbers of leaves in *E. melliodora*. The

results therefore suggest that although *E. melliodora* seedlings may be slightly more frost tolerant than those of *E. albens*, the difference is unlikely to explain the rarity of *E. albens*, relative to *E. melliodora*, at altitudes up to ~900 m a.s.l. or in 'frost hollows' at lower altitudes.

The fact that some *E. albens* seedlings survived in uninsulated pots at an altitude of 870 m a.s.l. at Orange, together with a natural occurrence of mature trees at 925 m a.s.l., is further evidence that alternative explanations need to be sought for the rarity of *E. albens* on the Central Tablelands. Though it is possible that it may have been more common before European settlement in the mid 1800s and since selectively removed, Cabbage (1902), who travelled widely in this area, did not record it at any site where it is currently absent.

Differences between delayed and early light treatments in the pot trial

Pots in the Delayed Light treatment were exposed, at least at the colder Orange site, to a longer period of frosting, which may have enhanced the formation of ice crystals in the soil. Hence, seedlings in this treatment had increased likelihood to damage by frost heave but a lower likelihood of cold-induced photoinhibition. As any one or more of these factors may have affected the results, they cannot be considered separately.

Despite deaths being more common at Orange in the Early Light treatment during early winter (Fig. 2), differences in survival rates between the two treatments were not evident by spring. Significant differences in growth indices were evident at Cowra and across sites for *E. albens* such that seedlings in the Delayed Light treatment were taller and/or had more leaves than those exposed to Early Light. However by January, following a period of enhanced growing conditions, these effects were far less pronounced (Table 4).

The pot trial results, together with natural occurrences on high altitude sites with easterly aspects, suggested that early morning sunlight's supposed adverse effect on frosted seedlings (photoinhibition) was not a useful hypothesis for explaining the presence/absence of *E. albens* on the slopes and tablelands.

CONCLUSIONS

It was hypothesised that the local distributions of *E. albens* and *E. melliodora* on the Central Tablelands (where *E. melliodora* is relatively common and *E.*

albens is rare) and adjacent Central Western Slopes (where *E. albens* tends to occur on upper slopes and *E. melliodora* on lower slopes) could be explained by different responses to frost. Pot trials at high and low altitude sites during the 1997 winter suggested that seedlings of both species were relatively frost tolerant. Though seedlings exposed to delayed morning sunlight were taller and/or had more leaves than those exposed to early morning sunlight, the differences were marginal and relatively short-lived when conditions for growth improved. Neither light treatment significantly affected seedling survival. Difference in frost tolerance between the two species was therefore an unlikely explanation for their distribution pattern on the slopes and tablelands.

Observations of the occurrence of *E. albens* at high altitude in the field also supported its apparent tolerance to low temperatures (at least up to 925 m a.s.l.) regardless of aspect. Differences in geology, slope, drainage and/or soils are probably more important factors than exposure to frost in explaining the localised occurrence of *E. albens* on the Central Tablelands and adjacent slopes.

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